LCA Commentary Articles

Life Cycle Impact Assessment: The Use of Subjective Judgements in Classification and Characterization

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The original "Code of Practice" workshop definition for Life Cycle Impact Assessment (LCIA) was: *Impact assessment* in LCA is a technical, quantitative, and/or qualitative process to characterize and assess the effects of the environmental burdens identified in the inventory component (p. 24, SETAC 1993b). Implicit in this definition were two far reaching conclusions:

1. some direct linkage existed between LCIA results and actual environmental effects

and

2. a technical or scientific procedure existed for all LCIA impact categories.

Both of these conclusions are now being reappraised.

SETAC, ISO, and ILSI, an organization with expertise in human health, have led the reappraisal of LCIA. These organizations first focused on the nature of the LCIA results. The LCIA results are now recognized as products of the inventory functional unit calculation, allocation procedures, unit process and system boundary selections, and system-wide aggregation convention (SETAC, 1997; ISO, 1997, 1998). As a consequence, LCIA results do not represent actual environmental effects or any prediction of effects, harm, or risks. There is no direct linkage of the LCIA results to actual impacts, and LCIA is distinguished from techniques such as environmental impact assessment or risk assessment (SETAC, 1997; SETAC-Europe, 1996; ISO, 1998; ILSI, 1996; WHITE et al., 1995). A revised, clearer description of LCIA results has emerged. LCIA results are defined as category indicators representing aggregated emission loadings and resources use for the selected impact categories (SETAC, 1997; ISO, 1998).

SETAC, ILSI, and ISO have reappraised the implicit definition of LCIA as a technical process and examined the role of subjective judgements in LCIA. Previously, although the selection of impact categories was viewed as subjective, the LCIA classification and characterization steps were still ideally technical and scientific processes (see p. 61, Nordic Ministers 1995). This view had been challenged on occasion by individuals who noted that many classification and characterization procedures were highly subjective (DE OUDE, 1993; ASSIES, 1994; PERRIMAN, 1995).

The early concept of LCIA as a technical process was based on the presumption that a common environmental mode of action or homogenous mechanism existed for each impact category. The common environmental mechanism would

1. define each impact category
2. be the basis for equivalency factors

and

3. support aggregation of equivalency conversions into a single category indicator (SETAC, 1993a, 1997).

On closer examination, a common mode of action or homogenous mechanism is not available for many impact categories, such as resources, ecotoxicity, and human toxicity. Instead, subjective judgements have often been used to develop impact categories, their equivalency factors, and to support aggregation (SETAC, 1997; ISO, 1998). In addition, emissions are released in different places and at different times, and the scientific basis available to aggregate these emissions into a single category indicator has been questioned (SETAC, 1997; ISO, 1998).

At least three circumstances can lead to the use of subjective judgements (SETAC, 1997):

1. Independent effects without a common mechanism are grouped into an impact category to reduce the number of categories to consider, such as for human toxicity
2. Substances are presumed to act together in combination so that the equivalency products can be aggregated into a single category indicator, such as for different nutrients in eutrophication

and

3. A wide range of site-specific considerations are replaced with a universal reference condition so that only one set of equivalency factors are used, such as for photochemical smog.

Table 1: Indicators for different emission types (see Table 3.3 p. 74-75, SETAC, 1997)

	Global Scale		Regional Scale		Local Scale	
Emission	**Indicator type**	**Comments**	**Indicator type**	**Comments**	**Indicator type**	**Comments**
Greenhouse gases	Environ-mental Equivalency (EEL)	Global scale process; system-wide aggregation is appropriate. Equivalence incorporates chemi-cal potency and environmental half-life.	global EEL	Category is global scale, but regional contribution can be coordinated with inventory boundaries.	global EEL	Category is global scale, but local contribution can be coordinated with inventory boundaries.
Acid deposition precursors	EEL	Acidification equivalents are worst case potential of emissions. Regional environmental process; global aggregation not environ-mentally plausible.	region-specific EEL	Regional scale process. Worst case. Need inventory boundary coordination. Atmospheric half-life & load to sensitive areas exceeding critical loads theoretically feasible using RA models.	local specific EEL	Local scale may include pro-cesses that release acidification precursors into a localized environment, i.e., coal mine sulfide leachates.
Smog precursors	approximate EEL	Regional or local process; global aggregation not plausible. Partial equivalence for reactivity of organic constituents. Subjective ratio for NO_x presumes conditions for temperature, sunlight, and other factors are common and universal to all sites.	region or local approximate EEL	Partial equivalence for organic constituents. Subjective ratio for NO_x presumes various conditions are universal. Must be coordi-nated with inventory boundaries. Atmospheric half-life / load to areas exceeding regulatory limits in theory feasible using RA models.	region or local approximate EEL	Partial equivalence for organic constituents. Subjective ratio for NO_x presumes various con-ditions. Local contribution can be coordinated with inventory boundaries. Atmospheric half-life / load to local areas exceeding regulatory limits in theory feasible using RA models.
Nutrients	loading score	Regional or local process; global aggregation not plausible; aggregation of independent nutrients using equivalency uses subjective judgement.	loading score	Aggregation of independent nutrients based on subjective judgement; only one limiting. Regional contribution can be coordinated with inventory. Requires inventory coordination with regional environmental data on sites.	local specific	Aggregation of independent nutrients based on subjective judgement; only one limiting. Requires site specific data. Direct models or measurements of dissolved O_2 possible, but requires inventory coordination.
Nonpolar narcotic chemicals	approximate EEL	Non-polar narcotics are locally additive where exposure is coin-cident; aggregation beyond local is not plausible.	approx. EEL	Non-polar narcotics are locally additive where exposure is co-incident; aggregation beyond local is not plausible.	approx. EEL	Non-polar narcotics are locally additive where exposure is coincident; requires inventory coordination and application at unit operation level.
other chemicals	approx. EEL normalized toxicity score	Not applicable. Aggregation of independent effects and sub-stances is not plausible. Combines different effects and independent substances using subjective judgement. Coincident exposure is not plausible. Growing agreement that environmental half-life is possible proxy for exposure. Some proposed methods incorporate.	approx. EEL normalized toxicity score	Not applicable. Aggregation of independent effects and substances is not plausible. Combines different effects and independent substances using subjective judgement. Coincident exposure is not plausible. Environmental half-life is possible proxy for exposure. Coordination with inventory required to improve exposure and half-life application.	approx. EEL normalized toxicity score	Not applicable. Aggregation of independent effects and substances is not plausible. Combines different effects and independent substances using subjective judgement. Coincident exposure requires inventory coordination. Environmental half-life is proxy for exposure. Some proposed methods incorporate.

These points are summarized from a SETAC work group report in Table 1 (see p. 74-75, SETAC, 1997).

SETAC (1997) has also noted that environmental mechanisms operate on different spatial scales (global, regional, and local) and temporal scales (decades, years, months, and days). LCIA has typically not attempted to adapt the inventory data collection, classification, and characterization to deal in with this wide array of different scales. This can lead to worst case assumptions and questions about the environmental relevance of the category indicator results.

In the case of acidification, 100% of the emissions are presumed to be converted to acids and all of the acid is presumed to be delivered to areas sensitive to acid rain. The actual, relevant quantity of acid delivered to sensitive areas is unknown and not represented by the category indicator.

In the case of photochemical smog, subjective judgements are used to select universal reference conditions for the reaction of organic compounds and nitrogen oxides. However, smog occurrence and magnitude depends on variable site conditions and the unique chemical mixture at the site. Thus, no generic or universal reference condition is environmentally relevant to all sites and conditions. The reference conditions also tend to be worst case, e.g., constant, year-round peak conditions of summer temperature and sunlight for ozone formation. Aggregation into a single category indicator also presumes the additivity of organic compounds and nitrogen oxides across different places and times.

In the case of eutrophication impact category, two separate mechanisms that can decrease dissolved oxygen are typically combined, e.g., nutrients and direct introduction of rapidly degradable organic matter. Subjective judgement is also often used to support the aggregation of different nutrients into a single category indicator. These judgements are used even though the nutrients, e.g., nitrogen and phosphorus, act independently and are rarely additive at any site. The SETAC work group also noted that subjective judgements are also needed to presume that nutrient releases are

1. additive across different places and times

and

2. result in equivalent severity (SETAC, 1997).

In the case of ecotoxicity, a common overall mechanism is lacking. Therefore, subjective judgements are used to group and to support the aggregation and addition of different elements into an indicator, e.g., general narcosis; acute toxicity, such as the LC_{50}; and chronic toxicity tests varying by medium, species, and endpoint. The subjective assumptions also presuppose concurrent exposure at the same place and time even though discharges occur at different locations or sites, e.g., separate rivers. Once more, determining environmental relevance and differences between systems using indicators based on such presumptions is difficult and requires additional data and investigation (SETAC, 1997).

Human toxicity encompasses numerous different effects that are independent and non-additive as previously recognized by several parties (Assies, 1994; de Oude, 1993; Perriman, 1995). The International Life Sciences Institute (ILSI) has sponsored an expert panel to review LCIA human toxicity methodology. The panel began by stating that aggregation of different toxic effects into a single indicator is inherently impossible on a scientific basis, i.e., different effects such as cancer, reproduction, and immunotoxicity are not additive. The panel further stated that any combination is a subjective process analogous to the valuation of greenhouse gases, acidification, and eutrophication (see p. vi and 18 of ILSI, 1996).

The ILSI expert panel noted that alternative judgements would likely change both the magnitude and even the order of the scores between two systems (ILSI, 1996). Further, as different parties have different, alternative values, the values held by one group should not be imposed on another. This makes transparency necessary in the use of subjective judgements in constructing indicator scores (ILSI, 1996).

The ILSI expert panel also noted that making relevant comparisons based on toxicity indicators is difficult. An important issue would be distinguishing if any significant differences actually existed between the compared systems. The ILSI panel used the ratio of the human health scores between systems as an indication that a difference could exist between two systems. Given the numerous uncertainties, the ILSI panel required a ratio be at least an order of magnitude or greater to undertake consideration that a meaningful difference between systems existed. Even this ten fold difference in system scores was not an automatic interpretation of a meaningful difference without detailed further reviews by expert toxicologists (ILSI, 1996).

A SETAC LCIA work group has echoed similar conclusions to the ILSI panel. Human heath and chemical toxicity indicators are pseudo-valuations, not technical measures and stated interpretive caveats for users: "*The sums of scores for different chemicals are not directly related to relative environmental toxicity of the combined emissions. Further, the ratio of toxicity scores for different chemicals and systems is not likely to be proportional to their relative environmental loadings and resource uses. Thus, when comparing two chemical inventories, sums of scores for all of the chemicals within each inventory should not be considered a technically valid measure of their relative toxicity.*" SETAC (1997).

In the case of resources, subjective judgements are needed to support aggregation of different materials into a category indicator (SETAC, 1997; ISO, 1998). Each individual re-

source, e.g., oil, iron ore, and copper, is typically independent of each other. Within renewable and flow resources, different sources are environmentally independent, e.g., forest renewal in Canada, Brazil, and Finland or fisheries in different regions are not directly linked. Thus, aggregation of different resources is a subjective judgement whose environmental relevance needs close scrutiny on a case by case basis.

There are other issues outside of classification and characterization. Current normalization procedures often use regulatory boundaries as a basis for normalization. This effectively ignores environmental scales or processes, e.g., regional processes that extend beyond national boundaries or where a number of local processes such as separate rivers are encompassed within national boundaries (SETAC, 1997). This implicitly replaces environmental processes with political considerations, while the LCIA results are still presented as an environmental comparison.

The above points are related to the ongoing debate about the use of LCIA. Many decision makers and audiences do not accept LCIA indicators as the sole basis for making environmental comparisons and claims (SETAC, 1977). This is especially true for external claims, i.e., comparative assertions in ISO terminology. These are key reasons that current committee draft of ISO 14042 states: "*LCIAs shall not provide the sole basis of comparative assertions of overall environmental superiority or equivalence.*" (ISO, 1998). For additional clarification, subjective judgements are referred to as value choices in ISO terminology (ISO, 1998).

SETAC has outlined several steps to deal with the issues of subjective judgements and environmental relevance (SETAC, 1997):

All subjective judgements should be reviewed in the study goal and scope definition for acceptance by parties initiating the study and the intended study audiences.

Subjective judgements should be transparently documented, including any compromise of or conflict with scientific knowledge, how the subjective judgement effects the individual category result, and how various subjective judgements effect the overall study result.

The environmental relevance of category indicators should be further evaluated using actual environmental data and information and other assessment techniques.

Subjective judgements and environmental relevance need to be specifically scrutinized by the peer or critical review process.

These SETAC proposals have been echoed in ISO. In fact, any overall comparative assertions must include other environmental information and assessments from outside LCA to overcome the limitations of LCIA (ISO, 1998).

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